Project Title: An Economic Analysis of Proposed Management Plans for the Public Oyster Grounds of the Rappahannock River

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Introduction

The objective of the project is to evaluate the economic benefits and costs of management strategies for public oyster grounds at the mouth of the Rappahannock River. Oyster populations in this area have been decimated by the impact of MSX. Restoration of this area was begun in 2000 with a repletion program involving the planting of oyster shell and construction of 3 dimensional reefs. Shell is now being planted on 29 bars covering 300 acres. The area was selected for restoration because the water is shallow enough to avoid the possible negative impact of low dissolved oxygen levels in the summer months.

A plan for a sustainable annual commercial harvest would alleviate the state from having to respond to ad hoc annual requests for opening up specific areas. Any management plan should maximize the biological and economic benefits from the harvest and the utilization of the state's resources. The policy goal is a management strategy that allows commercial harvest from some of these bars while maintaining the development of a potentially disease resistant broodstock population in non-harvested sanctuaries.

The management ground is divided into six areas, three above and three below the Route 3 Bridge. One area on each side of the bridge will be open to harvesting each year. Each area includes one or two sanctuaries, as well as other grounds that receive a planting of shell once every three years. Once a region is harvested, the bars receive a planting of shell to aid in recruitment of spat, with larvae coming from the sanctuary and other bars. The region is closed for a period of three years during which this recruitment grows to market size.

The net returns from restoration and harvest management strategies are estimated using a bioeconomic model of the oyster fishery developed with Stella modeling software. Parameters for the model are based on data for the mouth of the Rappahannock collected by VMRC and using other studies of oyster biology. The other sources include journal articles, various reports from VIMS, VMRC, the US Army Corps of Engineers, private consulting reports and environmental impact studies [Henderson and O'Neil 2003; Mann and Harding 1998; Wieland 2006]. These were reviewed for relevant information.

For each area, the model calculates recruitment based on the effect of the quantity of shell repletion and the population of mature oysters on the sanctuary and other bars. Spat and juvenile oysters suffer high mortality rates because of the high salinity and associated high impact of disease and predation. Three years following the shell repletion, a ground is open to commercial harvesting. Harvesting does not affect the mortality rate because oysters not taken are assumed to have died. Harvest costs are estimated based on a value per boat per day of harvest. Revenue is based on harvest size and the market price of oysters.

Shell planting and harvesting costs are used to calculate three types of net revenue. Revenue net of harvester costs is the net gain to the harvesters for their efforts. Revenue net of state costs is found as revenue minus the costs for shelling the grounds and purchasing large oysters. Revenue net of both costs is found as revenue minus both harvesting and state costs. This is the net return to the economy of the management program. While revenue net of harvester costs is found to be positive in some scenarios, revenue net of state repletion costs and revenue net of both are always negative.

Project Area

The Mouth of the Rappahannock is where the Rappahannock River flows into the Chesapeake Bay. The Rappahannock is a large tributary of the Chesapeake Bay. The Route 3 bridge runs approximately through the middle of this area. The area contains both public grounds and privately leased grounds [Berman et al. 2002]. The public grounds are those identified in the Baylor survey as naturally productive in 1894. These grounds are reserved for public use by Article XI of the Constitution of Virginia.

Production on both public and private grounds has been low because of the presence of diseases (MSX and Dermo) and predation (whelks and rays.) Harvesting on the public grounds was low to zero by the mid-1990s. Private lease activity is low. [Berman et al. 2002]. The area is also subject to freshets, inflows of low saline water from freshwater sources and anoxia, low levels of dissolved oxygen, both of which result in poor spat set and lower oyster populations.

A large scale restoration program, part of the Oyster Heritage Program, was initiated in 2000. In the first year, five one acre three dimensional reefs were constructed on bars at Parrots Rock, Drumming Ground, Temple Bay, Ferry Bar and Sturgeon Bar. Three additional reefs were constructed in 2001 at Broad Creek, Butlers Hole and Mosquito Point. Oyster shell, from shucking houses and dredged from fossil reserves, was the primary material used to build the reefs. The total cost for the reef construction was $940,507. The average cost per reef was $117,563. Intensive shelling of 29 surrounding bars covering 300 acres was undertaken during these two years at a cost of $1,497,502. Areas chosen for restoration were 18 feet deep or less to avoid the possible impact of anoxia in the summer months. The Virginia Coastal Zone Management Program provided some of the initial funding. Other funds came from VMRC and NOAA. Additional shelling on a rotating basis of these areas has continued since 2003. The cost of this shelling program from 2003 to 2006 has been $669,239. The average quantity of shell has been 165,582 bushels per year.

In 2002 commercial harvesters requested that VMRC open some areas to harvest. Areas above the Route 3 bridge were opened. This included 13 of the shelled bars, covering 145 acres. The harvest that year totaled a reported 13,773 bushels. For the following years, harvest on open areas was much smaller - 1,536 bushels in 2003 and 7,190 bushels in 2004. In 2006, a request was made to open areas below the bridge. This request was not granted.

To alleviate the state from having to respond to ad hoc annual requests for opening grounds to oyster harvesting, an oyster management plan was developed by the Virginia Oyster Heritage Program and recommended to the Virginia Marine Resources Commission on August 28, 2007 [VHOP 2007]. A Blue Ribbon Oyster Panel also made recommendations to the VMRC regarding oyster restoration strategies that support the type of policies recommended by the VOHP [Blue Ribbon Oyster Panel 2007]. These plans were approved by VMRC in August 2007. They call for continued funding of shell repletion programs and rotational harvests of publicly managed grounds in the Rappahannock.

For the mouth of the Rappahannock, the plan specifically calls for dividing the region into six areas; three above the bridge and three below. Each of the six management areas will contain broodstock sanctuaries which will not be harvested. Two areas, one above and one below the bridge will be open to harvest each year. Oysters smaller than 3 inches are to be returned overboard. Those over 4.5 inches are to be turned over to a Marine Patrol Offices at a designated sanctuary in an effort to promote the development of a disease resistant population. Watermen will be compensated for these. Entry will be limited. Gear types, season time and length and daily limits will be set annually by VMRC's Shellfish Management Advisory Committee. In order to assess the management program, a bioeconomic model for a typical area was developed during the summer of 2007 by researchers at Virginia Tech in conjunction with personnel at the Virginia Department of Environmental Quality and the Virginia Marine Resources Commission. Funding was provided through the Virginia Coastal Zone Management Program.

Bioeconomic model of the oyster fishery of the Mouth of the Rappahannock

Overview

A bioeconomic model of the oyster fishery at the Mouth of the Rappahannock was developed to generate estimated values for the net revenues from opening the public grounds on a rotational basis. The model portrays one of the rotational areas based on characteristics of the entire region. The model starts with no population of oysters, essentially the situation before the Oyster Heritage Program began with reef construction and shelling. Thus harvesting does not occur until the third year. It continues every third year.

The bars in each area are either included in a sanctuary or are open to harvest. The purpose of the unharvested sanctuary bars is to maintain a broodstock which supplies larvae for harvested bars. The population of mature oysters is assumed to be self-sustaining, i.e. each oyster just replaces itself. Oysters larger than 4.5 inches found on the harvested grounds are sold by the watermen to the Marine Resources Commission which then transplants them to the sanctuaries. Thus, the sanctuary population will be increasing over time as they are added.

The population of mature oysters on the harvested grounds results from a natural setting of spat. The broodstock, as well as mature oysters elsewhere in the area, are the source of larvae that settles on the substrate of these bars.

Oyster larvae need clean, hard substrate materials to set. However, due to sedimentation the substrate becomes covered in soil and less capable of attracting spat set. The management plan calls for repletion of both sanctuary and harvested bars once every three years by placing cultch material. High mortality rates for spat and juveniles result in a market size population of oysters three years later that is a small fraction of the original spat.

Once the population in an area has reached market size, the area is opened to harvesting by watermen using dredge vessels. Each vessel has two watermen working and works half of each season on each of the two opened public grounds. Given the high natural mortality rate, most of the oysters not taken are expected to die in the third year. The estimated revenue received by the watermen is a function of their catch and the market price. Revenue net of harvester costs is found as revenue minus costs borne by the watermen. This tells us the net return received by the watermen for their efforts. Revenue net of state costs is revenue received by the watermen minus the costs of shelling and purchasing large oysters. This tells us whether or not the revenue generated covers the costs of the state's management activities. Revenue net of both costs is found as revenue minus both of these costs. This is the return to the allocation of all resources accounted for in the model.

The Shell Repletion Program and Oyster Growth

Virginia has a long history of state financed shelling of public oyster grounds as a means of increasing the natural spat set and thus the population of market oysters available to watermen working these bars. Since oyster spat set is heavily dependent on the quality of the substrate, maintenance of the bars and reefs is critical to the success of the oyster restoration program. Average shelling 2002-2006 was 200,000 bushels per year for the region. Only two areas will be shelled each year, thus each would get half of this, 100,000. The shell repletion sector of the model is shown in Figure 1. Of this, half will placed on the harvested bars, the other half on the sanctuary bars. In the model, an initial stock of 50,000 bushels of shell exists on the harvested bars at the beginning. The shell however becomes covered with sediment. A decay rate of 50 percent per year is assumed drawing upon work by Smith et al. [2005]. When the grounds are first reshelled only 6,250 bushels of the original quantity are still clean enough to attract set. Overtime the shell stock grows slowly, such that by the end of the 15th year the stock has grown only to 57,142 bushels. The sanctuary bars are also subject to sedimentation. They also depreciate as a result of consumption by boring sponges. These bars therefore are replenished at a rate of 2,000 bushels per acre, a rate recommended by VMRC personnel and by the US Army Corps of Engineers [USACE 2007]. The amount of substrate reserved as sanctuary bars is initially set at 25 acres, thus these bar receive 50,000 bushels of shell.

The cost of the repletion program is based on a price per bushel of $1.20, the most recent price paid for cultch material in this region. The price is assumed to remain constant. This subsumes that the supply of material is large enough to maintain a supply at this price. The monetary cost for shelling the harvested bars with 50,000 bushels of shell then is $60,000. The cost is the same for the sanctuary bars. The costs for shelling the harvested bars are incurred three years before the harvest that the shelling promotes. The costs for shelling the sanctuaries occur six years before the harvest that the shelling promotes since this promotes the growth of mature oyster three years out which then provide the larvae that have matured into the harvested oysters. During these times the funds could have been invested in other public or private projects which could have earned a positive return. This opportunity cost of the funds is included in the model using a discount rate. The cost of the repletion is multiplied by e^{rt}, a financial function for continuous compounding in which r is the discount rate and t is the time period. For a discount rate of 5% and a time period of three years, this value is 1.16. Thus, the cost for bar repletion program is counted as $69,710. The cost for shelling the sanctuaries is $80,991. The combined cost of both programs for each period are shown in Table 2.

The repletion of the public bars increases the set of spat resulting from larvae produced by the broodstock and the existing population of oysters aged three or more years. The oyster maturation sector of the model is shown in Figure 2. The quantity of spat setting per bushel of shell is initially set at 900. For the 2000-2003 period of the repletion program, the ratio of shell to market oysters three years out was 1 bushel shell => 0.1 bushel of market size oysters. The range was from .05 to .19 of a bushel of market oysters. Given 600 shells per bushel of shell and 300 oysters per bushel of market oysters, the rate is 600 shells => 30 oysters. Given the model's survival rate of 30 percent of juveniles per year, 900 spat set early in the year would result in 270 spat by the fall and would eventually produce 25 market oysters. Actual spat counts have found 50-200 spat per bushel of shell in this area, so that even though the end result is slightly less than average, the spat count is slightly higher. The model therefore is calibrated initially so that each bushel of shell results in 900 spat on shell per bushel of shell or 1.5 spat per shell.

The spat set from the market oyster population is a function of the percent of the population that is female and the spat per female ratio. Each bushel of females produces 3 bushel equivalents of spat. Half of population is considered to be female in the third year of growth. Thus, 1.5 bushel equivalents of spat are produced for each bushel of market oysters on the public grounds and on the sanctuary reef.

Spat are subject to mortality before they reach the one year mark. The mortality rate for spat and juvenile oysters is set at 0.7 [Wesson; USACE 2007]. The spat mature into one year olds. These are subject to the same mortality rate so that only 30 percent pass on to be second year oysters. Likewise, only 30 percent of the second years pass on to market size by surviving one more year. The result is that only 2.7 percent of the original spat set survive to market size. Table 1 shows the quantity of market oysters that would result after each three year growth period.

Harvest Effort and Costs

Every third year the public grounds in one area are opened up to harvesting. The harvest effort and cost sector of the model is shown in Figure 3. If left unharvested, the natural mortality rate would result in a loss of 80 percent of the adults. The mortality rate is higher for older oysters as they are more susceptible to diseases. However, when the ground is opened to harvest, most oysters are taken before they die. Any oysters left behind are subject to the natural mortality rate. A harvest rate of 50 percent would leave 50 percent on the grounds. Of these, only 20 percent will survive until the next year. Thus, the market stock of oysters will have some positive rate of growth each year as long as the harvest rate is less than 100 percent.

With two areas open each year, watermen will spend one-half of each season on each area. With a twelve week, 60 day season, watermen work each area for 30 days in total. Each vessel has two watermen, each working a 7 hour day on the boat. The value of their time is estimated using the alternative wage that could have been earned in construction in surrounding counties, $11 an hour. Thus labor cost per vessel is $154 per day. The costs of the vessel are taken from a recent survey of Maryland watermen by Main Street Economics [Wieland 2006]. These costs include fixed capital costs which account for depreciation of the vessel and the opportunity cost of funds tied into holding the vessel. This later cost is calculated as 5 percent of the boat's present value. The annual costs are divided by 260 workdays in a year to find the daily cost. For smaller vessels this cost is $12 per day. Vessel cost also includes variable costs for annual dockage, maintenance of the hull, engine, propeller and gear, and the cost of a license. The cost of a license in Virginia is used here instead of the Maryland fees. These variable costs total $25 per day. Total vessel costs then are $37 per day. Fuel is estimated to cost $45 per day. The total cost for harvesting then is $134,520 per season. This value is shown in the revenue data in Table 2.

The cost to harvest the oysters in a season then depends upon the vessel cost per day, the number of days and the number of vessels. The number of vessels used is based on conversation with VMRC officials that 30-40 vessels operate at the start of the season though this may decline to 10 by the end of the season. Given other values and relationships, net harvester revenue is positive after year 6 only if the number of vessels is less than 20; thus the initial value is set at 19.

Unlike some economic models, effort is not a function of harvest, i.e. the watermen go out and catch what they can every day they can. The number of days and the number of hours per day is constant. The initial number of vessels is set. The model does not include any daily harvest limits or seasonal limits. Watermen will have to work the entire season in order to take the projected harvest. The number of vessels and the number of days in the season can be changed in order to assess plans that call for limits different from the initial values in the model. The harvest rate reflects the percent of legal size oysters taken from the public grounds in an area. The rate of harvest does not change with changes in any other factors. Differing harvest rates can be applied to see how revenue values change with fishing success.

Net Revenues

Revenue from the fishery is based on a market price of $30 per bushel, the average price in recent years. The net revenue sector of the model is shown in Figure 4. The higher the harvest rate, the higher the revenue and the higher will be any net revenues since the costs do not change with the harvest rate. Three accounting perspectives are used in determining net revenues from the fishery. From the perspective of the harvester, the net return is the difference between total revenue and total harvest costs. This is reported as revenue net of harvesters' costs. The other costs, for repletion and transplanting of large oysters, are borne by the state. From the state's point of view, the costs to the state are limited to the repletion and transplanting costs. If state officials want to know if the revenue generated by the plan exceeds the state's cost, the net revenue from this perspective is total revenue minus repletion and transplanting costs. This is reported as revenue net of state costs. From a social perspective, the question is does total revenue exceed the costs of all resources devoted to producing the harvest. Net social revenue then is total revenue minus harvester and repletion costs. This is reported as revenue net of both costs.

Results

The model was run with no existing market size population on the harvested bars in the public grounds. These grounds however do have an initial 50,000 bushels of shell. The sanctuary bars start with 40 bushels of mature oysters per acre. With the initial level of shell and the broodstock on the sanctuary bars, a population is established and begins to grow. By the third year a 4,090 bushel stock of market size oysters is available for harvest. For a 60 day season with 19 vessels and a 50 percent harvest rate, all the net revenues are negative. The level of takings at this rate for each period is shown in Table 1. The net revenues for each period are shown in Table 2. With another shelling, spat set from the newly established population on the public grounds as well as the sanctuaries, and no further interim harvesting, the population grows to 7,928 bushels in the sixth year. With this population level the harvest is still is not sufficiently large for the watermen to derive positive net revenue. By the ninth year the area is reaching an almost steady state of market size oysters of 9,052 bushels. Harvesters are then earning positive net revenue of $1,270 amongst all of them. Net revenues to the state are then -$21,700. When the harvesters' costs are also considered, the net returns to society are -$156,220. By the eighteenth year this increases only to 9,405 bushels. In the last year of the model run, 18 years out, the market population is 9,405 bushels. Net revenue to the watermen is $6,351.22 equal to $345 for each of the 19 vessels. Revenue net of the state's cost would be -$16,677. From the broad, social perspective however total costs exceed the monetary gains, so that the revenue net of both costs -$151,197.

Figure 1. Shell Repletion Sector of the Model

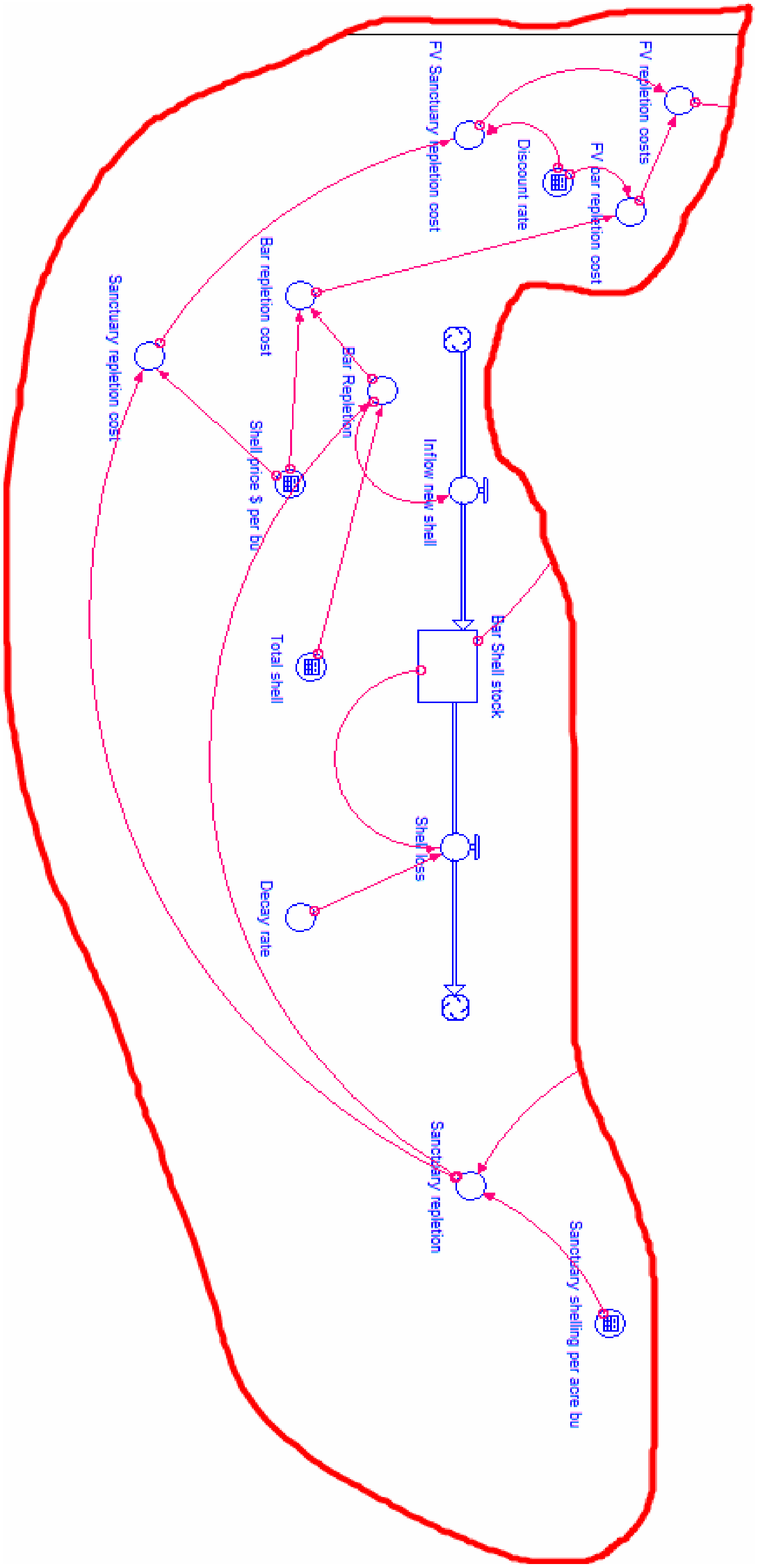

Figure 2. Oyster Maturation Sector of the Model

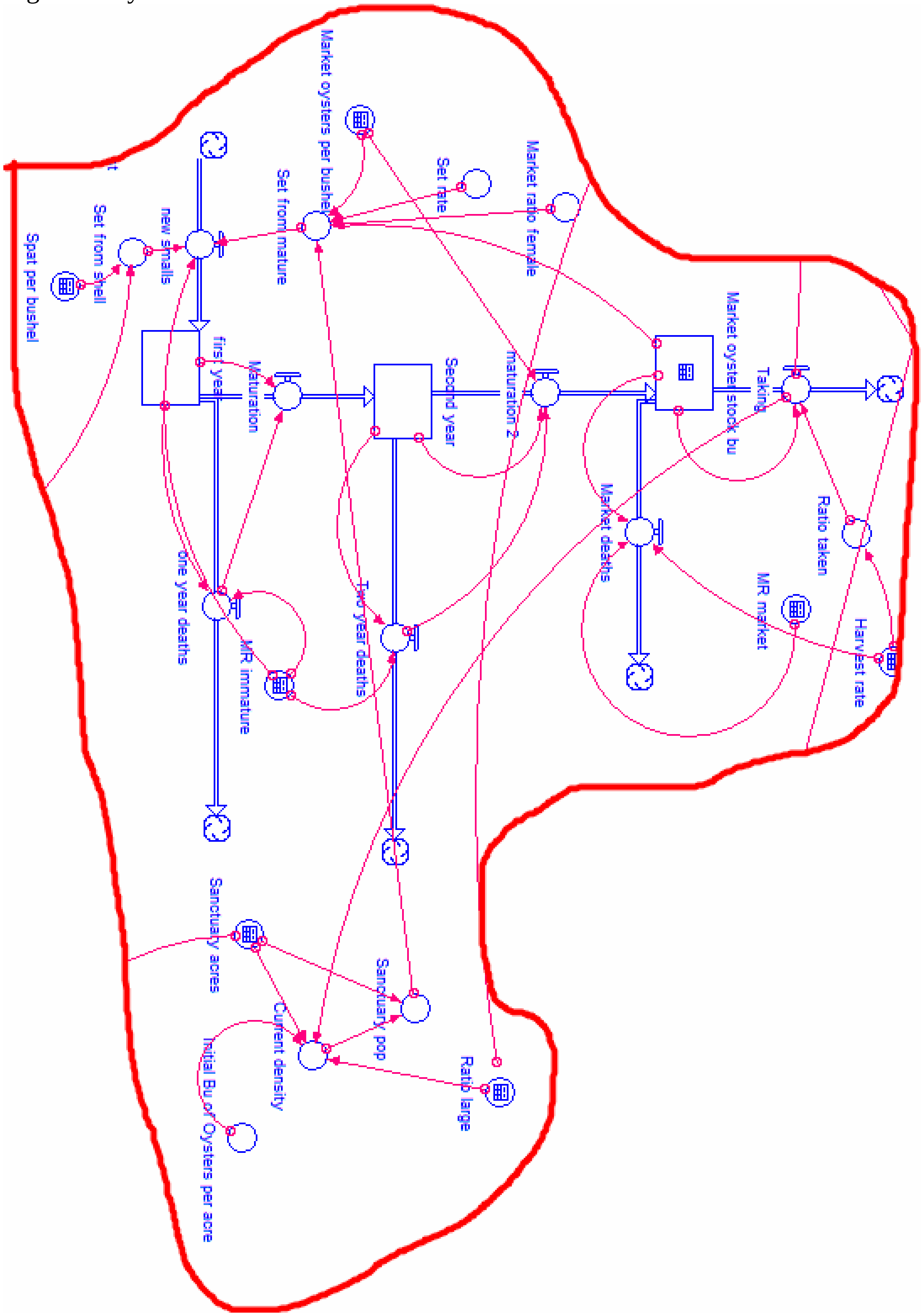

Figure 3. Harvest Effort and Cost Sector of the Model

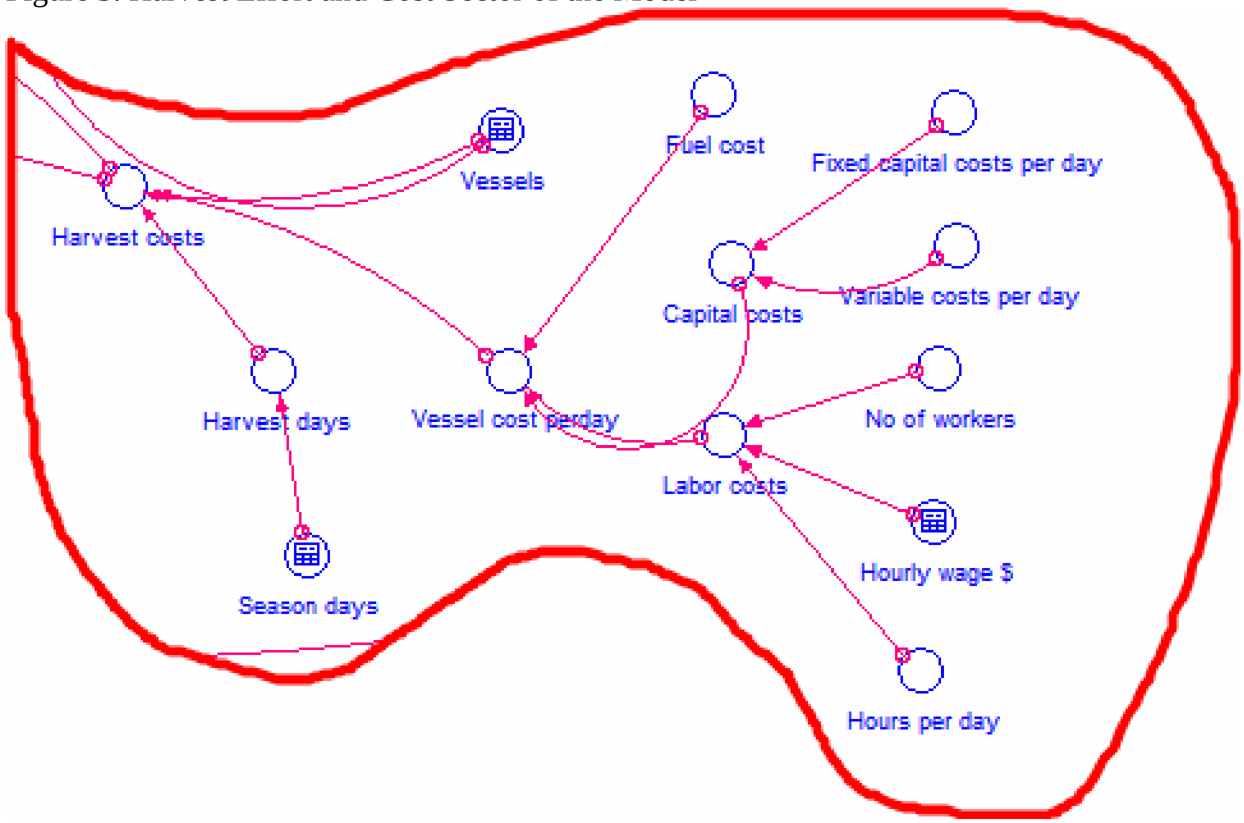

Figure 4. Net Revenue Sector of the Model

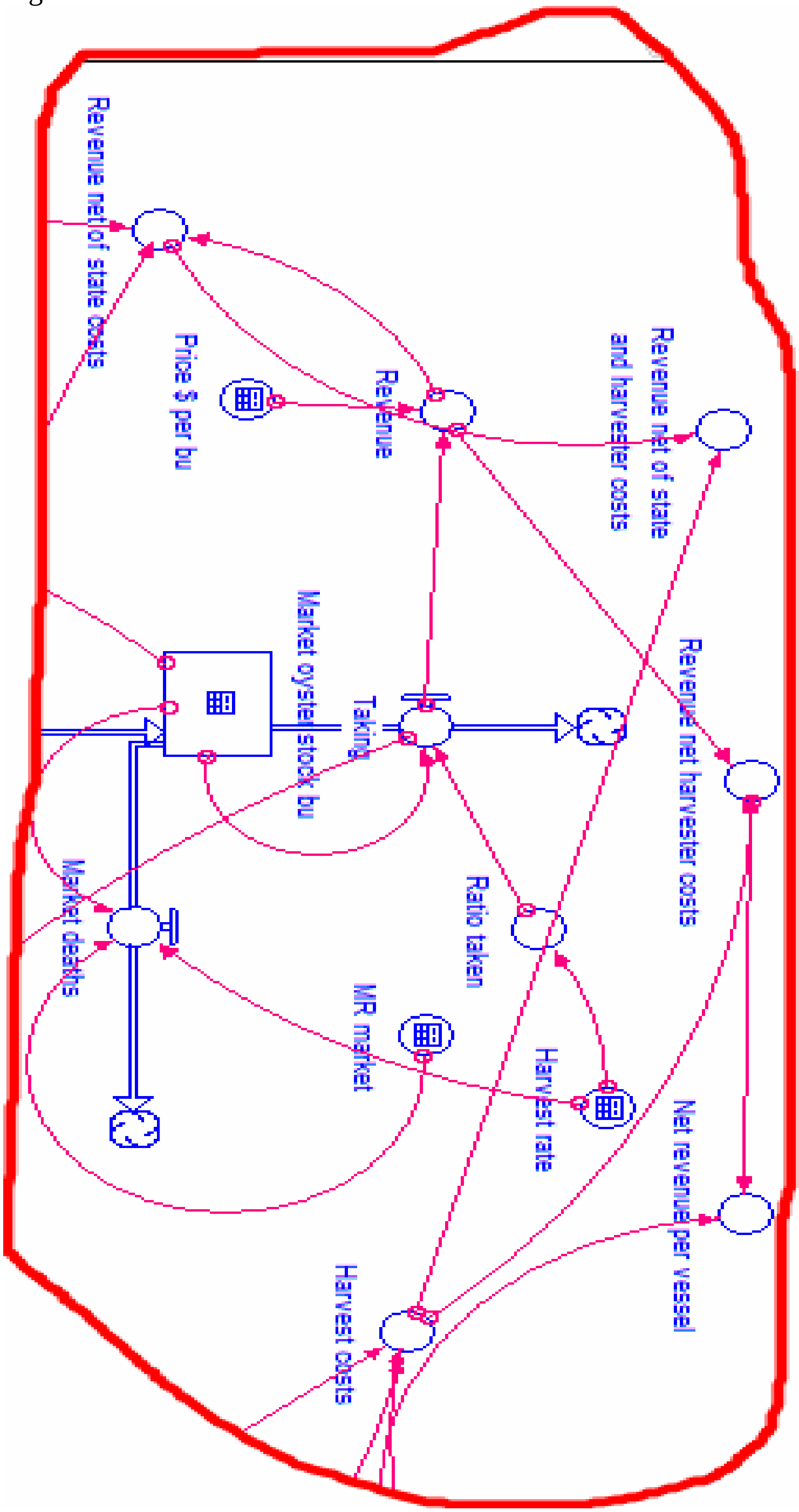

Table 1. Projected populations of market size oysters and taking by harvesters.

Years	Market oyster stock, bu	Taking, bu
3	4,090.50	2,045.25
6	7,928.31	3,964.16
9	9,052.67	4,526.34
12	9,328.58	4,664.29
15	9,391.41	4,695.71
18	9,405.20	4702.60

Table 2. Revenues and costs.

Years	Revenue	Harvesters' costs	Revenue net harvester costs	State costs	Revenue net of state costs	Revenue net of state and harvesters' costs	Net revenue per vessel
0	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
3	$61,357.50	$134,520.00	-$73,162.50	$150,701.58	-$92,411.96	-$226,931.96	-$3,850.66
6	$118,924.67	$134,520.00	-$15,595.33	$150,701.58	-$37,723.15	-$172,243.15	-$820.81
9	$135,790.12	$134,520.00	$1,270.12	$150,701.58	-$21,700.97	-$156,220.97	$66.85
12	$139,928.74	$134,520.00	$5,408.74	$150,701.58	-$17,769.28	-$152,289.28	$284.67
15	$140,871.22	$134,520.00	$6,351.22	$150,701.58	-$16,873.93	-$151,393.93	$334.27
18	$141,078.02	$134,520.00	$6,558.02	$150,701.58	-$16,677.47	-$151,197.47	$345.16

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